(12) **EUROPEAN PATENT APPLICATION**

(54) **Electrical compass.**

(57) A magnetic field detecting system for use with a flux-gate sensor (10) includes an oscillator (30), the output of which is applied to a digital bandpass filter (40, 42) and frequency divided and also applied to the sensor, and phase detectors (50, 52) such that the frequency and phase of the output signals from the flux-gate sensor have a predetermined relationship to the excitation signal. In one embodiment of the invention, the direction indicating output signals from the phase detectors are applied to an interface circuit (70) for a microprocessor (80) which converts the signals to a digital format employed for application to an alpha-type display (100) for displaying the octal magnetic orientation of a vehicle.

FIG 2

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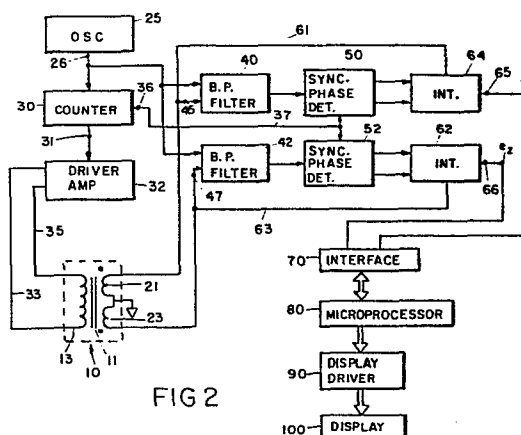
ELECTRICAL COMPASS

The present invention relates to compasses and, particularly, to an electrical circuit for processing signals from a flux-gate magnetic sensor used in a compass.

5.   Compasses for vehicles such as automobiles are, typically, after-market items of a relatively basic mechanical design. Such compasses, typically, attach to the dashboard of the vehicle and are of inexpensive construction including a compass card suspended by a

10.   pin bearing and mounted within a housing. Usually, they will include some elemental form of adjustment or compensation mechanism such as movable magnets for adjusting the compass to north and south, depending on the geographical area of use of the vehicle.

15.   The theory of operation of flux-gate magnetic sensors is well known and one application to the automotive environment is described in an article entitled "Magnetic Field Sensor and its Application to Automobiles" by Hisatsugu Itoh published on February

20.   25-29, 1980 by the Society of Automotive Engineers, Inc. as SAE Technical Paper No. 800123. In the commercial embodiment of this system, the bandpass filters incorporated to detect the second harmonic of the excitation input frequencies for the sensor must be

25.   critically tuned such that the quadrature information can be accurately detected and subsequently employed to drive a display of the vehicle heading. Not only must the system, however, be critically tuned, the stability of the bandpass filter and its power supply

30.   must be designed to be substantially drift free in order

to provide accurate information to the phase detectors such that accurate direction display results.

It is an object of the invention to overcome the stated deficiencies of the prior art flux-gate sensor

.5. application in the automotive environment, and to provide a more accurate and yet, more readily assembled and less expensive system.

According to one aspect of the present invention, a control circuit for use with an electrically operated

10. magnetic field detector employing a flux-gate sensor comprises: an oscillator for providing clock frequency output signals; counter means coupled to said oscillator and responsive to said clock frequency signals therefrom for providing an excitation frequency signal for

15. a flux-gate sensor and for providing a synchronization signal at a harmonic frequency of said excitation frequency; bandpass filter means coupled to said oscillator and including means for receiving signal information from a flux-gate sensor and responsive to

20. signal information and signals from said oscillator to provide signals at said harmonic frequency of said excitation frequency; and detection means coupled to said filter means and to said counter means and responsive to the synchronization signal and signals from

.25. said filter means for providing output signals representative of the orientation of a flux-gate sensor to an external magnetic field.

According to a second aspect of the present invention, a vehicle compass system comprises: a

30. flux-gate magnetic sensor having excitation input and

signal output terminals; an oscillator for providing
clock frequency output signals; counter means coupled
to said oscillator and responsive to said clock
frequency signals therefrom for providing an excitation
5. frequency signal applied to said excitation input of
said flux-gate sensor and for providing a synchronization
signal at a harmonic frequency of said excitation
frequency; bandpass filter means coupled to said
oscillator and to said signal output terminals of said
10. flux-gate sensor and responsive to signal information
from said flux-gate sensor and signals from said
oscillator to pass signals therethrough at said harmonic
frequency of said excitation frequency; detection means
coupled to said filter means and to said counter means
15. and responsive to the synchronization signal and signals
from said filter means for providing output signals
representative of the orientation of a vehicle in which
said flux-gate sensor is installed; and display means
coupled to said detection means and responsive to said
20. output signals for displaying the orientation in-
formation.

It will be seen that in compasses embodying the
invention both the bandpass filter and the phase
detector are frequency and phase locked to an oscillator
25. also employed to excite the flux-gate sensor such that
tuning-free assembly and operation of the system results.

In one embodiment of the invention, the direction
indicating output signals are applied to a suitable
interface circuit for a microprocessor. The micro-
30. processor converts the signals to a digital format
employed for application to an alpha-type display for

displaying, for example, the octal magnetic orientation
of a vehicle.

The invention may be carried into practice in
various ways but one vehicle compass embodying the
5.   invention will now be described by way of example with
reference to the accompanying drawings, in which:

Figure 1 is a fragmentary, top plan view of a
rearview mirror for a vehicle shown partly broken away
and incorporating a flux-gate type magnetic sensor;

10.   Figure 2 is an electrical circuit diagram partly
in block and schematic form showing a system embodying
the present invention; and

Figure 3 is an electrical circuit diagram in
schematic form showing details of a portion of the
15.   circuit shown in Figure 2.

Referring initially to Figures 1 and 2, a flux-
gate type magnetic sensor 10 is mounted within the
cylindrical barrel 20 forming a portion of the mounting
assembly for a rearview mirror 12 of a vehicle. The
20.   rearview mirror 12 including its housing 13 can be of
conventional construction and is coupled to the
cylindrical barrel 20 by means of a front ball joint
14 coupled to housing 3 by means of a stem 15. Barrel
20 includes a conventional socket for captively and
25.   pivotally holding ball 14 therein. Similarly, a rear
ball joint 16 including a stem 17 couples the opposite
end of cylinder 20 to a mounting bracket 18, typically
secured to the windshield of a vehicle by means of a
corresponding mating bracket adhered to the windshield
30.   or by connection to the vehicle headliner, in some

instances. Barrel 20 also includes a socket for
captively and pivotally receiving ball 16 such that
mirror 12 can be adjusted for rear vision by the
vehicle operator.

5.   Barrel 20 can be of conventional construction in
terms of the sockets for receiving front and rear
balls 14 and 16, respectively; however, the diameter
of the mid-section of the barrel 20 is slightly
enlarged to receive the flux-gate sensor 10. Sensor

10. 10 includes a toroidal core 11 having a generally
rectangular cross-section, an excitation winding 13
helically wound around core 11 and orthogonally aligned
first and second sensing windings 21 and 23, respec-
tively, poled as shown by the dots in Figure 2 and wound

15. in orthogonal relationship to one another about the
toroid as shown in Figure 1 to provide orthogonally
phased output signals of varying magnitude depending
upon the sensed external or earth's magnetic field.
Sensor 10 is secured within the non-ferro-magnetic

20. barrel by a suitable bonding or potting material 19 to
be horizontal when the mirror is in a normal adjusted
position. Also, the North-South winding 21 is aligned
to be parallel to the longitudinal axis of the vehicle.
Electrical leads from the windings 13, 21 and 23 are

25. extended from barrel 20 by a cable 27 extending between
the sensor 10 and the associated electrical circuits
shown in Figures 2 and 3.

       As shown in Figure 2, the compass system includes
an oscillator 25 which in the preferred embodiment is

30. an R-C oscillator having an output frequency of approxi-

mately 80 kHz at output terminal 26 thereof. The
output signal from oscillator 25 is applied to a
counter circuit 30 providing 400 Hz at output terminal
31 which is applied to a driver amplifier 32 which

5.   subsequently applies the 400 Hz signals to excitation
winding 13 of sensor 10 by means of conductors 33 and
35. Counter 30 also provides an 800 Hz signal at
output terminal 36 which is applied to synchronous
phase-detector circuits 50 and 52. The output

10. terminal 26 of oscillator 25 is also coupled to clock
input terminals of digital bandpass filters 40 and 42.
Filters 40 and 42 also include signal input terminals
45 and 47, respectively coupled to one end of sensing
coils 21 and 23, as shown in Figure 2, with the remaining

15. terminals of coils 21 and 23 commonly coupled to
system ground as shown in Figure 2. The outputs of
bandpass filters 40 and 42 are coupled to the input
terminals of the synchronous phase detectors 50 and 52
such that selected harmonic frequency signals, as

20. described in greater detail below, are applied to each
of the synchronous phase detectors which are actuated
by an enabling signal from counter 30 via an enabling
line 37 to apply positive and negative half-cycle
sinusoidal signals received from sensing coils 21 and 23

25. through bandpass filters 40 and 42 to integrating and
inverting amplifier circuits 62 and 64. The closed
loop gain of the system is controlled through a feed-
back path including conductors 61 and 63 extending
between the integrating amplifier 64 and the flux-gate

30. sense winding 21 and the integrator 62 and the flux-gate

sense winding 23, respectively. At the output
terminals 65 and 66 of integrators 64 and 62, respec-
tively, there is thus provided DC varying signals
e_1 and e_2, respectively, which represent the direction

5. information from sensing coils 21 and 23. The
amplitude and polarity of e_1 and e_2 varies with
vehicle direction with respect to the earth's magnetic
field. These DC varying signals are applied to a
suitable interface circuit 70, including for example,

10. suitable amplifiers and an AD converter for converting
the DC signal information to digital signals. The
interface circuit is connected to a microprocessor 80
which includes associated RAM and ROM memories with
the ROM programmed to mathematically derive an output

15. control signal in the form of the arc tangent of the
ratio $\frac{e_1}{e_2}$ to provide a digital output control signal
applied to a display driver circuit 90 for an alpha
display 100 such that octant direction information can
be displayed to the vehicle operator. The processing

20. of signals e_1 and e_2 from the integrator circuits 62
and 64 by a conventional microprocessor and program to
provide the $\tan^{-1} \frac{e_1}{e_2}$ in a digital format for octant
display of vehicle direction is entirely conventional.
Having described the overall system, a detailed

25. description of the preferred electrical circuit for
providing the direction signal information from the
flux-gate sensor is now presented in conjunction with
Figure 3.

Referring to Figure 3, the oscillator 25 provides

30. an essentially square wave output frequency of 80 kHz

applied to the input of the counter circuit 30 com-
prising, in the preferred embodiment, series coupled
counters 34, 38 and 39 which are commercially available
integrated circuit chips having model numbers indicated

5.   thereon in Figure 3 and each of which is coupled to
the +V power supply for receiving operating power as
well as to a system ground indicated by the triangular
symbol. A floating ground, indicated by a conventional
ground symbol, is also provided inasmuch as the system

10.   is adapted for vehicle use and only a positive battery
supply is typically available. Accordingly, a power
supply 110 provides both a system ground 112 and a
floating ground 114 which is coupled to the junction
of resistors 113 and 115 by an operational amplifier

15.   116 for impedance isolation. A filter capacitor 117
by-passes resistor 115 while a similar capacitor 118
AC couples ground 112 and 114. Capacitors 130 and
131 are coupled as shown to stabilize analog ground.

      Counter circuit 34 divides the 80 kHz signals
20.   from oscillator 25 to 16 kHz signals applied to the
input of counter 38 which divides the signals by ten to
provide 1600 Hz signals which are subsequently applied
to input terminals 13 and 3 of counter 39 with the
later signal being applied through an inverter circuit

25.   41. Counter 39 develops an 800 Hz generally square
wave output signal at pin 2 thereof and 400 Hz output
signals of opposite polarity at pins 15 and 14 which
are applied to the driver amplifier circuit 32 for
driving excitation coil 13 associated with the flux-

30.   gate sensor 10 such that the flux-gate core is driven

into saturation.   A capacitor 13' is in parallel with
coil 13 to suppress radio frequency interference.

Driver amplifier 32 is a push-pull type amplifer
having one current path consisting of the collector-

5.   to-emitter current path of a first NPN transistor 120
(driven by a positive going signal from terminal 15
of counter 39) through resistor 122, through excitation
coil 13, a second resistor 124, and a PNP transistor
126 biased in a conductive mode by an opposite polarity

10. signal from output terminal 14 of counter 39.   During
alternate half cycles of operation, the current path
is reversed and is provided by the collector-to-
emitter current path of NPN transistor 128 through
resistor 124, coil 13, resistor 122 and the emitter-to-

15. collector current path of transistor 129 to system
ground 112.   Thus, coil 13 is excited at a fundamental
frequency of 400 Hz and core 11 is driven into
saturation by the current through power transistors
120, 126 and 128 and 129, respectively at this

20. fundamental frequency.

As is known, the flux-gate sensor 10 operates
by the earth's or other external magnetic field off-
setting the hysteresis curve for second harmonic
frequency signals depending on the orientation of the

25. flux-gate sensor with respect to the earth's magnetic
field.   Thus, it is desired to detect and measure the
polarity and magnitude of the second harmonic (i.e.
800 Hz) signals from the detection coils 21 and 23
which are orthogonally related.   In order to synchronize

30. the detection of the second harmonic frequency signals

by phase detectors 50 and 52, the 800 Hz signals from
counter 39 are applied to input terminals 13 and 6,
respectively, of the phase detectors as well as an
inverted polarity 800 Hz signal applied through an

5. inverter circuit 51 to terminals 5 and 12, respectively,
of the phase detectors 50 and 52.

The input signals applied to phase detectors 50
and 52, however, are first filtered by bandpass filters
40 and 42 to substantially eliminate (40 db suppression)

10. all but the second order harmonic frequencies. This
is achieved by applying the signals from coils 21 and
23 to the signal input terminals 5 and 16 of bandpass
filters 40 and 42, respectively. Circuits 40 and 42
are each 1/2 of a commercially available National

15. Semiconductor integrated circuit chip, model number
MF-10, which is a switched capacitor sampled data
filter driven by the 80 kHz clock oscillator 25 and
having the RC components shown coupled to provide an
amplifier gain of approximately 1000 and having a Q of

20. 50 to substantially eliminate all but the second
harmonic frequency information coupled by capacitors
43 and 44 to the input terminals of phase detectors 50
and 52. The phase detectors are synchronized in phase
with this second harmonic information by the 800 Hz

25. signal applied to their clock input terminals from
counter 39 and inverter 51 such that signals are
applied to output terminals 2 and 3 of detector 50 and
9 and 10 of detector 52 only during a precise and
predetermined phase relationship to the fundamental

30. driving frequency of 400 Hz applied to driver amplifier

32.   In practice, the 800 Hz signals applied to syn-
chronize the phase detectors 50 and 52 are off-set
approximately 90° from the fundamental driving
frequency such that the transitions from logic zero

5.   to logic one and back occur during the enable portion
of the signals applied to detectors 50 and 52 at the
second harmonic frequency. Since the phase detectors
as well as the driver amplifier are locked to the clock
oscillator 25 through the counter circuits, this

10.   precise and predetermined phase relationship can be
selected and maintained to provide a maximum amplitude
output signal from the phase detectors for a given
output signal from the sensing coils 21 and 23 without
the necessity of tuning. The inverted output signals

15.   on pins 2, 3 and 9, 10, respectively, of detectors 50
and 52 are applied to opposite polarity inputs of the
operational amplifiers 64 and 62 which serve as inte-
grating circuits in conjunction with the feedback and
integrating capacitors and resistors coupled as shown

20.   in Figure 3 to provide DC output signals e_1 and e_2
at output terminals 65 and 66. Signals e_1 and e_2
indicate the direction of orientation of the flux-
gate sensor with respect to the earth's magnetic field
and, therefore, that of the vehicle in which the

25.   sensor is mounted. By providing signals e_1 and e_2,
corresponding to the orthogonal coordinates of direc-
tion and each of which can have a positive or negative
polarity relative to floating ground, all the in-
formation necessary for the vehicle heading is available

30.   in these two signals. As noted above, these analog

signals are converted into a digital format and applied
to a microprocessor for providing digital information
to a display 100, as shown in Figure 2.

    With the system described, therefore, signal

5. information from coils 21 and 23 are filtered and
detected in synchronism with the drive frequency
applied to excitation coil 13, therefore providing
precise, predetermined orthogonally related signal
information pertaining to the direction of orientation

10. of the flux-gate sensor with respect to a magnetic field
without the necessity of precisely tuning bandpass
filters. The utilization of such a system also elimi-
nates the need for providing a crystal control or
extremely stable oscillator since the oscillator

15. frequency is not critical. Various modifications to
the preferred embodiment of the present invention can
be made. Thus, for example, the display 100 may be
digital, as shown, or an analog type. If desired, the
microprocessor can provide information other than the

20. alpha information corresponding to the octant headings
(N, NE, E, SE, S, SW, W, NW) and, for example, can
display degree heading or other magnetic field
information. The location of the sensor 10, although
preferably shown in the barrel 20 of the rearview

25. mirror mounting assembly, can be positioned at other
locations although preferably in the headliner area
remote from the dashboard of the vehicle.

CLAIMS

1.   A control circuit for use with an elec-
trically operated magnetic field detector employing
a flux-gate sensor comprising:

an oscillator (25) for providing clock frequency
output signals;

counter means (20) coupled to said oscillator and
responsive to said clock frequency signals therefrom
for providing an excitation frequency signal (33, 35)
for a flux-gate sensor (10) and for providing a
synchronization signal (36) at a harmonic frequency
of said excitation frequency;

bandpass filter means (40, 42) coupled to said
oscillator and including means for receiving signal
information from a flux-gate sensor and responsive to
signal information and signals from said oscillator
to provide signals at said harmonic frequency of said
excitation frequency;   and

detection means (50, 52) coupled to said filter
means (40, 42) and to said counter means (30) and
responsive to the synchronization signal and signals
from said filter means for providing output signals
representative of the orientation of a flux-gate
sensor to an external magnetic field.

2.   A control circuit according to Claim 1 in
which the bandpass filter means (40, 42) is a digital
sampled data filter.

3.   A control circuit according to Claim 1 or
Claim 2 in which the harmonic frequency is the second
harmonic.

4.   A control circuit according to any of Claims
1 to 3 in which the detection means includes digital
phase detection means (50, 52) having a signal input
coupled to the output of said bandpass filter and
having clock input means (37) coupled to said counter
means for synchronizing the detection of signal in-
formation with said excitation frequency signal.

5.   A control circuit according to Claim 4 in
which the detection means further includes integrating
means (64, 62) having input means coupled to said
phase detection means for providing an analog output
signal therefrom.

6.   A control circuit according to Claim 5 which
includes circuit means (70, 80, 90) coupled to said
integrating means (64, 62) for providing a display (100)
of the orientation of a flux-gate sensor.

7.   A control circuit according to any of Claims
1 to 6 in which the excitation frequency is about 400 Hz.

8.   A vehicle compass system comprising:
a flux-gate magnetic sensor (10) having excitation
input and signal output terminals;
an oscillator (25) for providing clock frequency
output signals;
counter means (30) coupled to said oscillator and
responsive to said clock frequency signals therefrom

for providing an excitation frequency signal applied
to said excitation input (33, 35) of said flux-gate
sensor and for providing a synchronization signal at
a harmonic frequency of said excitation frequency;

bandpass filter means coupled to said oscillator
and to said signal output terminals of said flux-gate
sensor and responsive to signal information from said
flux-gate sensor and signals from said oscillator to
pass signals therethrough at said harmonic frequency
of said excitation frequency;

detection means (50, 52) coupled to said filter
means and to said counter means and responsive to
the synchronization signal and signals from said
filter means for providing output signals representative
of the orientation of a vehicle in which said flux-
gate sensor is installed; and

display means (100) coupled to said detection
means and responsive to said output signals for
displaying the orientation information.

9.   A system according to Claim 8 in which the
said harmonic frequency is the second harmonic.

10.   A system according to Claim 8 or Claim 9
in which the bandpass filter means is a digital
sampled data filter.

11.   A system according to Claim 10 in which
the detection means includes digital phase detection
means having a signal output coupled to the output
of said bandpass filter and having clock input means

coupled to said counter means for synchronizing the
detection of signal information with said excitation
frequency signal.

12. A system according to Claim 10 in which the
detection means further includes integrating means
(64, 62) having input means coupled to said phase
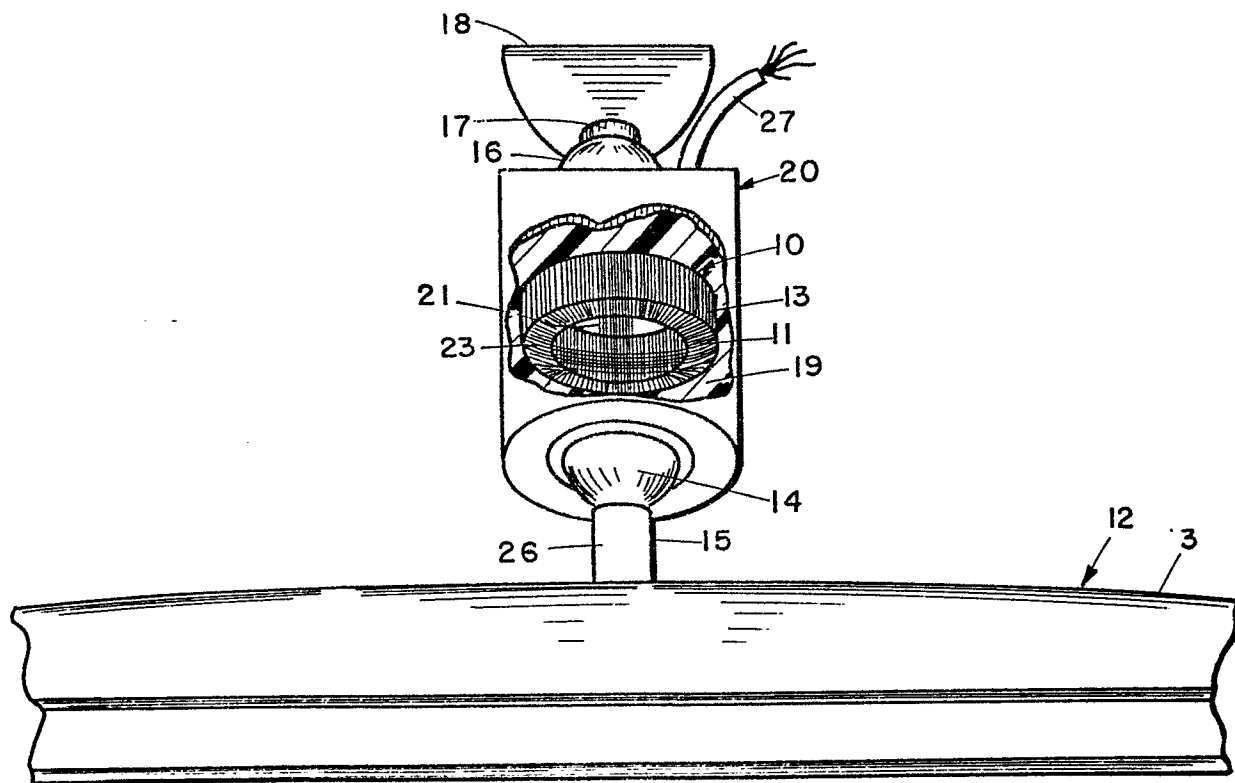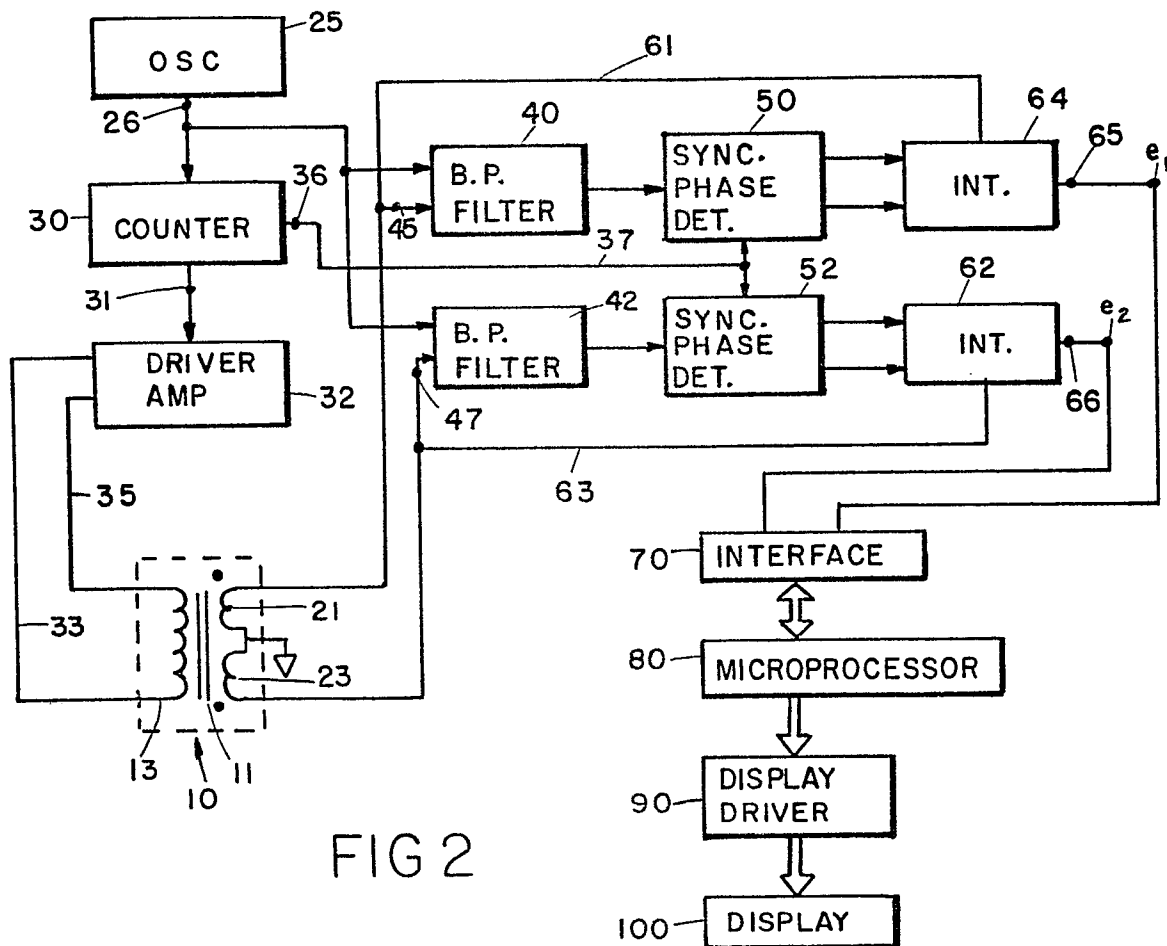detection means for providing an analog output signal
therefrom.

FIG 1

FIG 2

FIG 3